

ON THE PATHOLOGICAL CHANGES OF THE
NERVOUS ELEMENTS OF THE SPINAL CORD,
AS OBSERVED IN TWO CASES OF ACUTE
TRAUMATIC MYELITIS.

By DR. H. D. SCHMIDT,

PATHOLOGIST TO THE CHARITY HOSPITAL OF NEW ORLEANS.

(With fifteen illustrations.)

IN the July number, 1883, of this JOURNAL a paper was published, in which I described the pathological changes observed in the cerebro-spinal axis of a case of chronic myelitis of nineteen years' standing, which chiefly consisted in a congestion and degeneration of almost all the blood-vessels, a fibrinous exudate effused into the larger and smaller septa of the affected parts of the cord, and giving rise, by its pressure upon the nervous elements of the white and gray substances, to atrophy of the nerve-fibres and degeneration of the ganglionic bodies. In contradistinction to these changes, produced very gradually in the course of many years, I shall now describe those which I observed in the spinal cords of two cases of acute traumatic myelitis, effected in the short space of a small number of days, or even hours. The first of these cases I had an opportunity to observe personally, enabling me to state the most prominent ante-mortem phenomena; whilst in the other case, which, soon after the reception of the injury, terminated fatally, only the injured portion of the cord was

handed to me for microscopical examination, the autopsy not having been performed by myself or by my assistant.

CASE 1.—William Brown (white), twenty-six years old, received an injury of the spinal cord on July 4, 1880, by falling, probably in a state of alcoholic intoxication, from a second-story window. As the accident happened on a plantation located some distance from New Orleans, nearly three days had elapsed when he arrived at the Charity Hospital on July 7th, 5 o'clock P.M. At this time, when admitted to the ward, the patient was still able to move his fingers, though he had no power to grasp or hold any thing, as, for instance, a cup of water. He could slightly bend the fore-arms, but was perfectly unable to raise the arms, except by simultaneously moving the shoulders. His lower extremities were, on the contrary, completely paralyzed.

When I observed the patient myself, in the forenoon of July 8th, the whole body, with the exception of the head and neck, appeared to be paralyzed. He was perfectly helpless, so that his body had to be turned or rolled around by the nurse whenever he was fatigued from resting in one position. He could still move his head freely, and his mind was clear, for he intelligently answered all questions put to him. His sight and hearing were unaffected, though both of his pupils were contracted, responding to light but very feebly. There was no difficulty observed in his respiration, and he could easily protrude his tongue in a straight direction. The patient suffered from no pain, except in the back of the neck and in the bladder. In the former region the pain increased when pressure was made upon the spinal column as far down as the fifth cervical vertebra ; below this point it commenced to decrease, leaving ordinary sensation downward to the fifth dorsal vertebra. On the chest sensation was present as far down as the fifth rib. Below these points, however, sensation was completely lost, and anæsthesia prevailed over the whole surface of this part of the body.

Over the last sacral vertebra the skin was intensely congested, presenting a dark-blue patch of about one and a half inch in diameter. Though at this time no ulceration could as yet be discovered, the congested portion of the skin was converted into an ulcer before the death of the patient.

The pain in the bladder, already mentioned, was increased by pressure, and this organ being affected with motor-paralysis, the urine had to be removed by means of the catheter. The pain

here generally manifested itself by a sensation of fulness of the organ, inducing the patient to ask quite frequently, about every four or five hours, to have his urine drawn off, though the quantity removed seldom amounted to more than four or five fluid drachms. On the day preceding death, July 9th, the urine, on standing, showed a deposit, which chiefly consisted of pus-corpuscles. The temperature of the patient was always high, though he did not feel the heat; it ranged from 102° to 103° F. until five hours before death, when it rose to 106° F. There was also a profuse perspiration over the whole body including the head. The pulse was very rapid, though not full, until death. On July 9th the motor-paralysis was complete in the trunk and extremities, the patient being only able to move the head. The respiration had become labored, remaining so until death. The pain in the back of the neck had increased, but the mind was still clear. On July 10th the pain had extended to the head, and steadily increased in severity until 6 o'clock, P.M.; the patient, having intensely suffered during the day, became delirious, and died in this condition at half-past 11 o'clock. A few hours before death an involuntary copious evacuation from the bowels took place.

The autopsy, made eleven hours after death, revealed a considerable ecchymosis in the subcutaneous tissue of the back of the neck and thorax, extending from the fourth cervical to the seventh dorsal vertebra. The muscles of this region also were bruised and ecchymosed, the ecchymosis extending laterally as far as six inches from the median line. From the first lumbar vertebra to the sacrum there was a considerable œdema, extending to the sides of the body. The ligaments connecting the laminæ and spinous processes of the seventh cervical and first dorsal vertebræ were found ruptured; the same was the case between the fourth and fifth dorsal vertebræ. On the external posterior surface of the dura mater, between the seventh cervical and first dorsal vertebræ, a coagulum of blood, one half inch in diameter and one eighth inch in thickness, was met with; this had very probably been formed from blood entering from without. In opening the dura mater after its removal,

with the spinal cord enclosed, from the spinal canal, it was found that the cervical portion of the cord had undergone certain macroscopical changes by the injury it had received from the fall of the patient. The most striking of these changes consisted in a constriction of the cord, about one inch in length, and situated in the spinal foramen of the first dorsal vertebra. The circumference of this constricted portion amounted to about two thirds of that of the normal cord. Above and below the constriction the cord presented certain hernia-like bulgings, caused, as the subsequent microscopical examination of the longitudinal sections showed, by a displacement of tracts of nerve-fibres of the white columns. In fact, the whole cord, from a point between the third and fourth roots of the cervical nerves to about two inches below the constricted portion, appeared pressed out of shape, so that, after being hardened in Mueller's fluid, and transverse sections made, the respective gray and white substance presented a somewhat rhomboid form as shown in figure 1. This portion of the cord, also, had lost its normal consistency, and easily yielded to pressure, though it was still sufficiently consistent to be hardened for the purpose of making thin sections. The constricted part, however, was completely softened by degeneration. The cervical portion of the cord, above the roots of the third pair of spinal nerves, as well as the dorsal and lumbar portions below the injured parts, had preserved their normal consistency.

As the spinal cord, at the opening of the dura mater, was found lying straight in the lumen of this membranous tube, the question may be asked in what particular manner the constriction as well as the distortion above mentioned were produced. In considering, therefore, the nature of the injury a little closer, it becomes obvious that the macroscopical changes wrought upon the cord could only have

been produced by a very forcible process; and, as the ligaments connecting the laminae and spinous processes of the seventh cervical and first dorsal vertebræ were found ruptured, I presume that, by the force incident to the fall of the patient's body from the height of two stories, a transient lateral and rotatory dislocation of these vertebræ—implicating, of course, their articular processes—took place. Now, in consequence of the rotation of one vertebra upon the other, the cord, at this place, became pressed between the margins of these bones, similarly to any other soft body put between two dull and badly fitting scissor-blades, resulting in the constriction, while, at the same time, the neighboring parts of the cord experienced a forcible twisting, giving rise to the distortion mentioned above.

The larger and smaller vessels of the pia mater were congested, the anterior and posterior spinal arteries being completely filled with blood. An exudation, with a great number of exudation-cells had taken place into the subarachnoid space of the cervical region, with a thickening of the arachnoid membrane.

The spinal cord, being removed from the dura mater, was then hardened by leaving it for some time in Mueller's fluid, and then subjecting it to the action of alcohol. In this manner the affected portions of the cord above and below the constriction acquired, in the course of a few weeks, a consistency sufficient to allow the making of thin horizontal and vertical sections. The constricted part, however, forming the centre of the injury, having, by the pressure which it experienced, undergone to a certain extent degeneration and disintegration, always remained soft.

Five days after the death of the patient, when this portion of the cord had acquired a slight consistency, I prepared minute fragments of it by teasing them with the points of fine needles for microscopical examination. The latter

showed a great number of minute portions of the medullary sheath (fig. 7) escaped from the nerve-fibres that had been crushed and torn by the injury; furthermore, numerous distorted nerve-fibres and naked axis-cylinders torn from the interior of the latter either by the injury or by the manipulation of the needles. A number of ganglionic bodies, with or without processes or their fragments, were also observed, either disintegrating or having undergone fatty degeneration. Among the nervous elements numerous capillary hemorrhagic centres, fragments of small blood-vessels, or blood-corpuscles, disseminated throughout the tissue, were also observed. All these changes, however, ought to have been expected as the natural result of the severe crushing or bruising to which the cord had been subjected at this point, for which reason they offer nothing characteristic to the true inflammatory process going on above and below. We shall therefore now turn our attention to the examination of those parts of the cord bordering the constriction, the elements of which had, to a certain extent, remained intact.

As already stated, these portions of the cord had become sufficiently hardened to enable me to make very thin horizontal and vertical sections, which were stained with picrocarmine. Of these the vertical ones remained perfectly intact, while the horizontal ones broke into a few pieces during the cutting, on account of the displacement of some of the white columns above mentioned; but as the whole was held together by the pia mater, I was still able to mount a number of them in glycerine or Canada balsam. The microscopical examinations, however, were not confined to these sections; on the contrary, they were chiefly made on carefully teased preparations obtained from these sections, or from minute fragments of the hardened cord. In truth, the examination of sections, especially those mounted in

Canada balsam, would give us but a very poor insight into the pathological condition of the component elements of the spinal cord, if not associated with that of carefully teased preparations.

Let us now consider the condition of these elements, and commence with the smaller blood-vessels. It has already been stated, that all those vessels of the pia mater, discernible with the naked eye, were found congested. The same was the case with the most of the more minute vessels, the arterioles, capillaries, and venules. Not only were they found filled with blood-corpuscles, but, moreover, certain pathological changes—such as an increase of the protoplasm, of the small cells in the walls of these vessels—were observed. The minute vessels of the cord itself were found in the same condition. Here the increase of the protoplasm, and its subsequent fatty degeneration with that of its nuclei, had, in some instances, assumed enormous proportions, as may be seen in fig. 8. Besides, upon the outer surface of a number of these vessels, a finely granular fibrinous exudate, as well as capillary hemorrhages, in the form of minute collections of blood-corpuscles, were also observed. The latter were most probably produced by the sudden application of pressure, caused by the injury, or by the concussion incident to the fall of the patient.

In passing over to the nervous elements, we shall first take notice of the ganglionic bodies, which, unlike those met with in the soft and degenerated constricted portion of the cord already mentioned, were here found mostly intact with their processes and perfectly stained with carmine, indicating that they had not suffered from any degenerative changes. On the contrary, judging from the intensity of their carmine staining, I rather presume them to have been in a state of parenchymatous inflammation, during which their power of absorbing the carmine was increased. Never-

theless, in a few of these bodies I observed the yellow staining of the picric acid preponderating over the carmine, indicating the commencement of degeneration.

The most striking pathological changes, however, were observed on the nerve-fibres of the white columns, particularly those taken from the upper and lower parts of the constriction, near those hardened portions of the cord from which the sections had been made. Here the nervous elements had not attained so high a degree of degeneration and disintegration as in the middle of the constricted part. A greater number of the axis-cylinders of these nerve-fibres were observed to be more or less swollen, some even to an enormous extent. They were either still surrounded by their medullary sheaths, or laid entirely or partially bare, as may be observed in figures 2, 3, 4, 5, and 6. Whether these fibres lost their medullary sheaths by the crushing force of the injury to which the cord at this locality had been subjected, or by the manipulation with the needles during the teasing process, is difficult to positively determine; but as this part of the cord was, to a certain extent, hardened, and even stained, before the preparations of these fibres were made, I am inclined to attribute the entire or partial removal of their medullary sheaths to the force of the injury. The most of these axis-cylinders were more or less stained with carmine, while a smaller number of them had refused the staining material, having, to a certain extent, already undergone degeneration. In many instances (fig. 2, *d*, and figs. 5 and 6), the swelling of the axis-cylinder was longitudinally quite extensive, whilst in others it had assumed the form of a varicosity. Although the swollen axis-cylinders still showed their granular anatomical composition, the regular linear arrangement of the minute granules, fused with one another, and representing the originally component elements of the ultimate fibrillæ of the axis-cylinders.

ders, had disappeared. In those unstained by the carmine, however, numerous minute fat-globules had already made their appearance. The medullary sheath of almost all nerve-fibres in these preparations was deranged, its fibrillar layer being displaced to form larger or smaller varicosities (fig. 2, *a*, *b*, and *c*, and fig. 3), while its fibrillæ appeared separated.¹ The displacement of the medullary sheaths of these fibres may have been due, on the one hand, to the swelling of the axis-cylinders, and on the other, to the concussion and pressure which the fibres had to bear from the injury. Scattered among the nerve-fibres just described, a considerable number of fragments or small masses of the medullary sheath, escaped from the torn nerve-fibres, were also observed (fig. 7). These masses of nerve-medulla were likewise met with in the different sections of the cord, where they easily might have been mistaken for the product of a fatty degeneration. In examining the vertical sections, I found the nerve-fibres presenting the same varicosities as in the fibres of the teased preparations above

¹ I still regard the medullary sheath of the double-contour nerve-fibre as consisting of two distinct parts, viz.: the "medullary" and the "fibrillar" layers, such as I have mentioned in my paper on the "Dark or Double-bordered Nerve-fibre," published by the Royal Microscopical Society of London in 1874 in the May number of the former *Monthly Microscopical Journal*. At that time, though I frequently observed the fibrils of the fibrillar layers appearing in the form of loops, I regarded this appearance as being produced by artificial changes taking place within the nerve-fibre, and erroneously imagined them to lie parallel to one another in the normal condition of the nerve-fibre. The numerous examinations, however, which I have made on the nerve-fibres since that time, together with a series of special researches on the subject which I made in 1881,—the outlines of the results of which I embodied in a paper "On the Influence of the Structure of the Nerve-fibre upon the Production and Conduction of Nerve-force," published in the proceedings of the Cincinnati meeting of the Amer. Assoc. for the Advancement of Science,—have thus far convinced me that these fibrils are arranged in the form of loops, placed obliquely between the tubular membrane (sheath of Schwann) and the axis-cylinder, giving rise to the so-called "incisures" of the medullary sheath. The interspaces left by these fibrils are filled up by the medullary layer, or true nerve-medulla, a semi-liquid fluid of a fatty nature. As soon as my time will permit, I shall complete these researches, and publish the results in a special paper on the subject. As regards the double-contour nerve-fibres of the cerebro-spinal axis, on which no sheath of Schwann can be demonstrated, I still presume that, though they are held apart by the fibrillæ of the neuroglia, some pseudo-membrane, in the form of a dense layer on the surface of the medullary sheath, too thin to manifest itself by a double contour, exists, preventing the fusion of the nerve-medulla of contiguous nerve-fibres.

described; they were very probably produced by the same causes, though here the swollen axis-cylinders were not so numerous, and had not attained the enormous proportions, as in the neighboring constricted portion of the cord. In these sections, also, the above-mentioned hernia-like bulgings, directly above and below the constriction, were distinctly seen, and found to be produced by the displacement of certain tracts of nerve-fibres, chiefly belonging to the white lateral columns, which had assumed a wavy course.

The examination of portions of this spinal cord taken from the dorsal and lumbar regions showed, in a lesser extent, the same condition of the blood-vessels as in the cervical region, while the nervous elements appeared normal.

In comparing, now, the pathological changes found in the nervous elements of the case under consideration, which has to be regarded as one of acute traumatic myelitis, with the changes which I observed on the elements of the cord of the case of chronic myelitis, referred to in the beginning of this paper, a great difference becomes apparent. In the latter or chronic case, the pathological process consisted in the exudation of a finely granular product or exudate from the blood-vessels, which, by its pressure, slowly caused a simple atrophy of the nerve-fibres not accompanied by any disturbances of their axis-cylinders or medullary sheaths; while in the other case, distinguished by the symptoms of acute myelitis, we find the axis-cylinders more or less swollen by the effects of the acute inflammatory process, and the medullary sheaths completely deranged. Only the blood-vessels appear in a somewhat similar condition in both cases.

CASE 2.—Wm. Walker, a negro, was admitted to the Charity Hospital during the morning of December 23, 1881. A bale of cotton had fallen upon the back of his head, fracturing, as the

autopsy subsequently showed, the fourth and dislocating the third cervical vertebra, and causing an injury to the cervical portion of the spinal cord, from which he died during the following night, early on December 24th.

The clinical history, such as furnished to me by the gentleman who had been in charge of the case, resembles that of case I, and is as follows :

There was motor paralysis of the upper and lower extremities, and anæsthesia from the shoulders down to the toes. The loss of sensibility was so complete, as to allow the insertion of a pin into the arm of the patient without the latter feeling it. There was no pain anywhere, except under the chin and on the occiput. The head of the patient was abnormally movable. Respiration was entirely diaphragmatic. The pulse was quick but regular, while the temperature of the body ranged from 101 to 103° F. There was also retention of the urine.

As the details of this short history are of but secondary importance to this paper, I shall at once proceed to the description and discussion of the pathological changes, which I observed in the elements of the spinal cord.

The portion of this cord which was handed to me for microscopical examination presented the same peculiar constriction as in the case above described, with the only difference, that in the case of the negro the constricted part was not quite as long as in the spinal cord of the white patient. In accordance with the locality of the dislocated and fractured vertebræ, the injured part of the cord belonged to the upper part of the cervical enlargement. The same hernia-like bulgings and wavy protuberances directly beyond the constriction, produced, as in the former case, by a displacement of certain tracts of the white columns, were also observed here. After the whole portion of the cord was hardened first in Mueller's fluid and then in alcohol, thin horizontal and vertical sections were made, and stained with picro-carminé ; a number of them were mounted

in Canada balsam and glycerine, while others were teased with fine needles. The horizontal sections, I may state, being very thin, broke, as in the former case, into several pieces, owing likewise to the displacement of those tracts of nerve-fibres before mentioned, while the vertical sections remained intact.

The microscopical examination of these sections showed that the changes which had taken place in the nervous elements, particularly the nerve-fibres, were of the same nature as those observed in the former case. The greater number of the nerve-fibres presented varicose swellings, as represented in fig. 9. In many instances the axis-cylinders, being well stained with carmine throughout the whole section, could be distinctly seen to traverse or to fill up the varicosities (figs. 10 and 11). In some nerve-fibres even, the axis-cylinder was observed to present several windings in its passage through the varicosity (fig. 10). In a number of varicosities even, the swollen parts of the axis-cylinder appeared curved (fig. 11). The varicosities which these nerve-fibres presented, depended, of course, upon a derangement of the medullary sheath, which in these places was shortened upon itself, probably by the sudden jerk or pressure which the spinal cord experienced during the accident; and the winding, serpentine course observed on some axis-cylinders (figs. 9 and 10), as above mentioned, was undoubtedly produced in the same manner. Some idea of the intensity and suddenness of the jerk, or jolt, to which the cord was subjected, may be formed by the examination of fig. 12, which represents an axis-cylinder, perfectly stained with carmine, wound upon itself by several curves in a varicosity of the medullary sheath, which was separated from the nerve-fibre during the infliction of the injury. The fibrils of the fibrillar layer, of course, became also separated from one another by the same jerking force.

The swollen parts of the axis-cylinders, however, being, in this second case, always met with within the varicosities of the nerve-fibres, lead to the idea, that the swelling, indicative of a parenchymatous inflammation, was preceded and called forth by the molecular disturbance incident to the bending and winding of this anatomical component of the nerve-fibres. Besides, many of the varicosities may not have been quite as large, as seen in the sections, directly after the infliction of the injury, but may have subsequently increased in size by the swelling of the axis-cylinders. The comparative difference which existed in the diameters of the swollen axis-cylinders may be seen in fig. 13, representing the transverse sections of four nerve-fibres taken from the white columns of a very thin horizontal section of the spinal cord above the constriction; the axis-cylinders here are well stained with carmine.

Scattered among the distorted nerve-fibres of both horizontal and vertical sections were observed a great number of small masses and fragments of the medullary sheath, escaped from the nerve-fibres torn by the injury upon the cord. Some of these masses (fig. 14) exhibited a fatty lustre, as if they had undergone fatty degeneration.

The ganglionic bodies observed in the sections were found highly stained with carmine, but appeared morphologically normal.

The smaller blood-vessels both of the pia mater and the spinal cord were found congested. The more minute vessels of the cord, also, were mostly observed to be filled with blood-corpuscles, and many of them met with surrounded by a granular fibrinous exudate (fig. 15).

In making a comparison of the pathological changes observed in the anatomical elements of the spinal cords of the two cases of acute traumatic myelitis above described,

it becomes evident, that they were produced not only by the same pathological process, that of acute inflammation, but also by the same mechanical causes. The only difference observed in the histological changes of the nervous elements was owing to the degree, or extent, to which the inflammatory process had advanced, and, accordingly, manifested itself in the difference existing in the condition and dimensions of the swollen axis-cylinders. Thus, while the swellings of the axis-cylinders of the nerve-fibres in the cord of the second case had, in the short space of fifteen or sixteen hours, only advanced to form a simple varicosity (fig. 11), we behold in the first case—lasting more than six days before ending fatally—the same swellings extended more or less in a longitudinal direction over the axis-cylinders, while, at the same time, fatty degeneration has made its appearance in a number of the latter. We may therefore conclude, that if the negro had lived some days longer, the swellings of the axis-cylinders of his spinal cord would likewise have longitudinally extended, accompanied by fatty degeneration in its incipient stage.

Explanation of the Illustrations.

FIG. 1.—Section of the cervical portion of the spinal cord of case 1, showing the distortion of the gray and white substances.

FIG. 2.—*a*, a nerve-fibre exhibiting some slight varicosities; the swollen axis-cylinder protrudes from the torn end of the fibre; *b* and *c*, two nerve-fibres exhibiting more extensive varicosities and a hernia-like protuberance; *d*, an enormously swollen axis-cylinder deprived of its medullary sheath.

FIG. 3.—A swollen axis-cylinder covered by its medullary sheath.

FIG. 4.—A swollen axis-cylinder of a fine nerve-fibre.

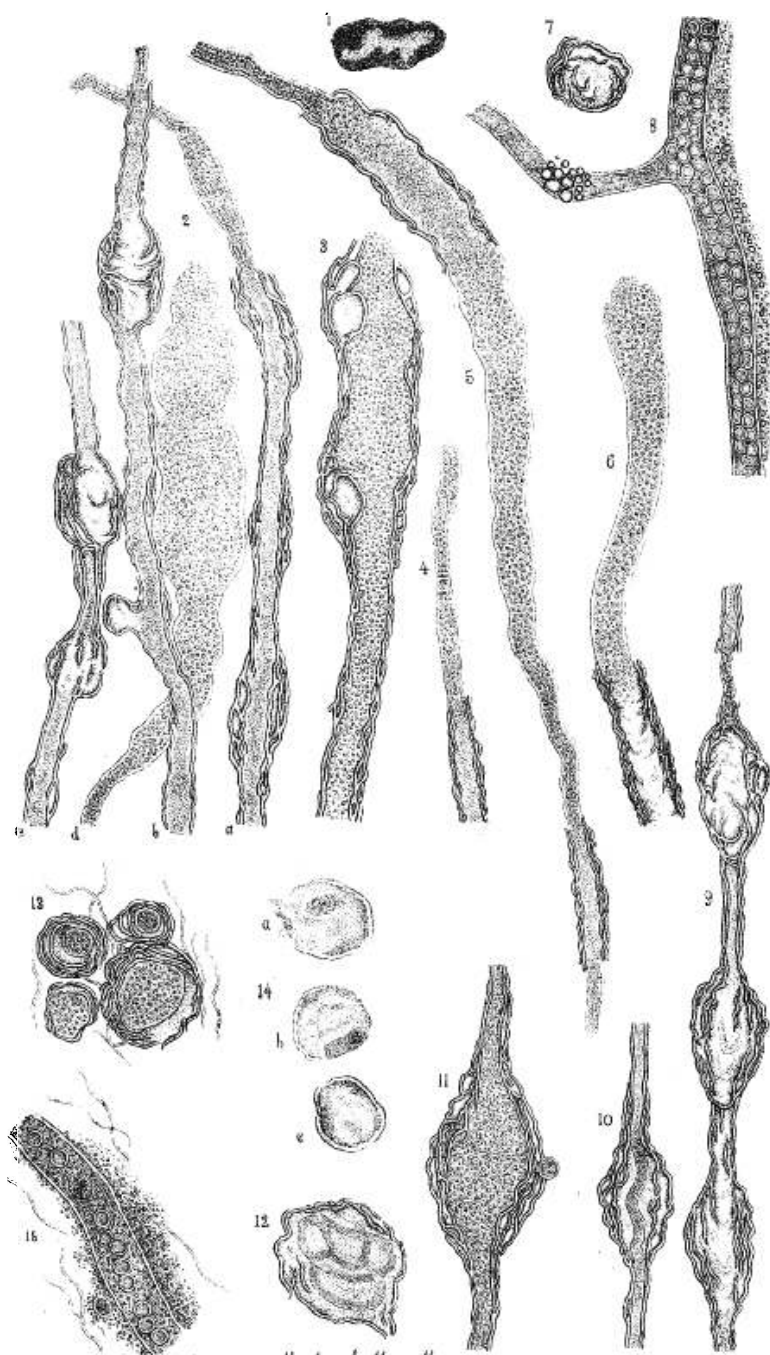
FIG. 5.—A swollen axis-cylinder of great length.

FIG. 6.—A swollen axis-cylinder with a club-shaped extremity protruding from the medullary sheath.

FIG. 7.—A fragment of medullary sheath escaped from the torn end of a nerve-fibre.

FIG. 8.—A minute blood-vessel showing the protoplasm of the minute cells of its walls enormously increased, with fatty degeneration of the nuclei.

FIG. 9.—A nerve-fibre exhibiting the character of the varicosities, as observed in the spinal cord of case 2.



drawn upon the stone by the author

FIG. 10.—Shows the curves and windings which an axis-cylinder has assumed in the varicosity of a nerve-fibre.

FIG. 11.—Portion of a nerve-fibre with a varicosity filled up by a swollen axis-cylinder.

FIG. 12.—A varicosity detached from the nerve-fibre and containing a portion of an axis-cylinder rolled up by several windings.

FIG 13.—Transverse section of four nerve-fibres showing the difference existing in the diameters of the normal and swollen axis-cylinders ; a few fibrillæ of the neuroglia are seen to adhere to the fibres.

FIG. 14.—Fragments of the medullary sheath undergoing fatty degeneration ; *a* and *b*, fragments with small portions of the fibrillar layer still adhering ; *c*, fragments of nerve-medulla completely degenerated.

FIG. 15.—A portion of a minute blood-vessel from the spinal cord of case 2, surrounded by a granular fibrinous exudate to which a few neuroglia fibrillæ are seen adhering.